TECHNICAL REVIEWERS' RATING SUMMARY

G-010-B
"Surface Tiltmeter Study of a Bakken Fracture Stimulation"
Submitted by: Marathon Oil Company
Principal Investigator: Ken Dunek & Glynn Williams
Request for $120,000; Total Project $240,000
Duration: 5 months

		Technical Reviewer			Average
Rating	**Weighting**	**10B-01**	**10B-02**	**10B-03**	**Weighted**
Category	**Factor**		**Rating**		**Score**
Objective	9	4	3	4	33.0
Achievability	9	3	2	4	27.0
Methodology	7	3	3	5	25.7
Contribution	7	5	2	4	25.7
Awareness	5	4	3	2	15.0
Background	5	4	2	2	13.3
Project Management	2	3	2	3	5.3
Equipment Purchase	2	5	2	5	8.0
Facilities	2	3	2	4	6.0
Budget	2	5	2	5	8.0
Average Weighted Score		191	121	189	**167**
Maximum Weighted Score		250	250	250	**250**

OVERALL RECOMMENDATION

FUND			
FUNDING TO BE CONSIDERED	**X**		**X**
DO NOT FUND		**X**	

G-010-B
"Surface Tiltmeter Study of a Bakken Fracture Stimulation"

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Section B. Ratings and Comments:

1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Oil and Gas Research Council goals are: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear. Please comment:

Reviewer 10B-01 (Rating: 4)
The proposed surface tiltmeter mapping study of a hydraulic fracture treatment of a horizontal lateral in the Bakken formation, if successful, should promote efficient, economical, and environmentally sound exploration, development, and utilization of North Dakota's oil and gas resources by allowing operators to optimize the orientation of their horizontal Bakken wellbores. Knowledge of the fracture orientation relative to the wellbore will allow optimization of fracture conductivity for increased productivity and greater ultimate recovery. This will allow each well to more effectively produce the oil and gas in place in the Bakken reservoir. More efficient production of oil and gas could allow more acreage to be productive, resulting in more wells drilled, and as a result, preserving existing and creating new jobs for North Dakota workers. More wells drilled will help to stabilize, grow, and create opportunity for the oil and gas industry in North Dakota. If this project is successful, it will help encourage others to utilize new technologies.

Reviewer 10B-02 (Rating: 3)
The objective of this project is clear, but I do not believe it is consistent with the goals of the NDIC/OGRC. The project would be specific to the Middle Bakken. At this time there are many unknowns more important to the play.

Marathon's Response
From the viewpoint of Marathon's well construction team, optimum wellbore orientation is one of, if not the most important unknown that could lead to a significant improvement in well performance because it leads to the determination of the type of fracture stimulation that is utilized. Furthermore, fracture orientation is the basis for optimizing wellbore orientation.

Reviewer 10B-03 (Rating: 4)
Although the description of the objective presented in the text of the proposal seems to be limited it can be inferred from the text that the primary goal of the proposed study is gathering information for the optimization of well geometry and enhancing production from the middle Bakken Member. This knowledge is certainly desirable for successful exploration of ND hydrocarbon reserves. However, precaution should be taken in extrapolating the results of the study to a broader area.

Marathon's Response
This is true. Other productive areas in the state may require further testing. If this project is successful, however, it would prove up the methodology to use in other areas.

2. With the approach suggested and time and budget available, the objectives are: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable. Please comment:

Reviewer 10B-01 (Rating: 3)
I have concerns the project will have some difficulties in regard to timeframe, but that it probably can be completed within the first 6 months of 2007. Those concerns are with extreme cold weather related problems that may effect operations in the early months of 2007. Timing for the start of the project is contingent on when drilling would start and the amount of time required for drilling and subsequent completion work prior to the fracturing treatment. The budget cost given for the portion of the completion involving the tiltmeter design, placement, fracture treatment monitoring, and analysis seems reasonable. However, the inclusion of a concept design and cost estimate from the tiltmeter vendor would have been very helpful in this evaluation phase.

Marathon's Response
It is Marathon and Pinnacle's belief that it will be easier to work in the winter with frozen ground than in the spring with thawing ground. The timetable and budget estimate included in Section 6.0 – Timetable, and Section 7.0 – Budget is the timetable and budget estimate from the tiltmeter vendor.

Reviewer 10B-02 (Rating: 2)
Considering the limited information presented, it is questionable if the surface tiltmeter can measure the orientation of a fracture created more than 10,000 feet below the surface.

Marathon's Response
Pinnacle has recently conducted a tiltmeter study in the Bakken for another customer. The results are proprietary, but Pinnacle indicated that they were able to acquire quality data.

Reviewer 10B-03 (Rating: 4)
The subcontractor intended for work completion has all the expertise necessary to perform the proposed study. The budget looks reasonable. However, funds intended for data acquisition and interpretation imply that no in-depth analysis will be held by the subcontractor. With these limited analytical conclusion the primary investigator should be sure that his task force will be able to make competent decisions.

Marathon's Response
The $35,000 line item in the budget for Data Acquisition and Analysis contains funds for in-depth analysis on the part of Pinnacle.

3. The quality of the methodology displayed in the proposal is: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average. Please comment:

Reviewer 10B-01 (Rating: 3)
While the concept of tiltmeter determination of hydraulic fracture orientation is well documented and proven in the industry, it has seen limited utilization in the Williston basin. It should be incumbent on the prospective grant recipient to show this technology does not face technical hurdles in this project that may prevent it from providing the intended result. Without any design from the vendor including their analysis of the applicability of this technology to this application, it is difficult to definitively determine the quality of the methodology. In the past, the tiltmeter technology has sometimes had problems resolving the surface distortion or tilt produced by fractures created at this depth. Also, what effects will complex hydraulic fractures created from a

horizontal wellbore have on the ability of the post treatment analysis to resolve a fracture orientation related to the in situ stress field? Complex fracture geometry has been suggested from other diagnostic techniques as common in fracture treatments initiated from a horizontal well, especially if minimal wellbore isolation within the horizontal section is utilized, i. e. an openhole or non-cemented liner completion.

Marathon's Response
As part of the design process, we are reviewing options for enhancing the resolution of the measured data, such as increasing pump rate during the fracture stimulation job. Another possibility is to mechanically limit fracture initiation to a specific point in the wellbore for an initial fracture treatment, and then open up the entire lateral for a second treatment. These options are still being evaluated as part of the ongoing detailed design process.

Reviewer 10B-02 (Rating: 3)
In my opinion the quality of the methodology displayed would decrease as the distance from the created fracture increases. It appears the surface tiltmeter would need to be correlated with additional information to produce satisfactory results at the depth of the Middle Bakken.

Marathon's Response
See previous comment indicating successful application of surface tiltmeter technology in the Bakken.

Reviewer 10B-03 (Rating: 5)
The proposed methodology is reported to be effective for the achievement of the project goal. It can be suggested that additionally three-arm caliper logs be used for studying well-bore elongation (breakouts), which has been shown to provide reliable information for the determination of stress orientation.

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Oil and Gas Research Council goals will likely be: 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant. Please comment:

Reviewer 10B-01 (Rating: 5)
The successful implementation of the proposed work and the production of quality results that stand up to technical review would provide a very valuable and useful scientific and technical contribution to the industry and would meet the NDIC/Oil and Gas Research Council's goals of promoting the use of new technologies and ideas that would positively impact the oil and gas industry in North Dakota.

Reviewer 10B-02 (Rating: 2)
At the current stage of development of the Middle Bakken, I believe there are other unknowns that need to be determined before this project is significant.

Marathon's Response
The Middle Bakken play does carry a set of unknowns that are not addressed by this project; however, well construction and effective fracture stimulation are significant variables that impact the recovery of oil and the economics of the play.

Reviewer 10B-03 (Rating: 4)
Fracture network in Bakken Member can be considered one of the most important factors influencing productivity. Thus, better understanding of fracture geometry can significantly contribute to the improvement of well design and completion. Meanwhile it should be noted that

even advanced well design can provide no significant improvement, see comments in the end of the review.

5. The principal investigator's awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional. Please comment:

Reviewer 10B-01 (Rating: 4)
The investigator's knowledge of the relationship of hydraulic fracture orientation to the existing stress field orientation is good. There were no references to published literature given in the proposal and references to the technology in the proposal appear to be personal knowledge. However, the investigator's knowledge of the tiltmeter technology appears to be sufficient for the purposes of this project. The investigator's appears to rely on the tiltmeter service vendor for technical expertise in the application and interpretation of the data, and as such, the vendors should be considered a referenced resource in the same manner as published data.

Reviewer 10B-02 (Rating: 3)
The investigators appear to have adequate knowledge of research activity and published literature.

Reviewer 10B-03 (Rating: 2)
It is impossible to assess the principal investigator awareness of the current research activity and published literature as no references are given in the proposal.

6. The background of the investigator(s) as related to the proposed work is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional. Please comment:

Reviewer 10B-01 (Rating: 4)
There is no indication in the proposal that either of the referenced investigators has direct experience with the use of tiltmeters to determine hydraulic fracture orientation, and indirectly, the orientation of the in situ stress field. However, both have listed significant experience in the field of oil and gas production and should be familiar with hydraulic fracturing monitoring technologies such as those proposed. Both also work for a global oil and gas exploration and production company that maintains an active technology group, so exposure to this technology at some level is likely to have occurred. Internal technology information and resources within their company are likely to be significant. Due to the recent entry of their company into the Bakken formation play of the Williston basin, they may have to initially rely on some amount of local knowledge in regard to drilling, completing, and producing in this area, especially in regard to an unconventional resource play like the Bakken.

Reviewer 10B-02 (Rating: 2)
The investigators background as related to the proposed project is limited.

Marathon's Response
The project will utilize Pinnacle Technologies, an industry leader in fracture mapping, for this project.

Reviewer 10B-03 (Rating: 2)
The proposal does not contain indication of any geomechanical expertise within the project task force, which seems to be extremely important for the success of the project.

Marathon's Response
The project will utilize resources for geomechanical expertise on an as-needed basis, including Pinnacle Technologies, as well as Dr. Bob Barree, of Barree and Associates, who is an acknowledged industry expert in hydraulic fracturing and the underlying geomechanics.

7. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very good; or 5 – exceptionally good. Please comment:

Reviewer 10B-01 (Rating: 3)
The timeline for the project is fairly complete, but may be somewhat optimistic based on the previously mentioned cold weather conditions that may impact some of the early steps scheduled to occur in the historically very cold winter months. One consideration is how long the operator will be willing to have the well remain shut-in, waiting on the completion and availability of vendors, if weather issues do become a problem. Timing and communication issues with all involved vendors are critical with the continued shortage of certain equipment and related technologies in the Williston basin. However, this concern is not unique to this area or to this project alone, and the operator's choice of a relatively large 6 month window is likely prudent. Without a proposal from the tiltmeter vendor, it is difficult to be certain of the accuracy of the cost estimate, but it does appear reasonable, barring the unforeseen. Again, operating in the dead of winter may cause costs to increase, particularly in the area of well preparation and other day to day operations.

Marathon's Response
As this project goes forward, a requirement will be that the tiltmeter array must be installed, with proper background measurements completed, before progressing with the frac job. The proposed schedule is based on having the tiltmeter array in place at least 6 weeks prior to the earliest possible date for the frac job in order to have plenty of time for the array sites to settle and measure background data. However, if it turns out that the frac job must be delayed in order to better accommodate the tiltmeter project, then that delay will happen.

Reviewer 10B-02 (Rating: 2)
Approximately 83% of the total cost of the project is for installation, maintenance, and reclamation of the array. Not being familiar with the tiltmeter and array installation and maintenance, a detailed explanation of costs is needed.

Marathon's Response
The project is acquisition intensive thus the strong cost weighting toward field activities identified in the cost breakdown of the application is appropriate.

Reviewer 10B-03 (Rating: 3)
The part of the work plan containing analytical work is not elaborated. However, this is the part which is anticipated to provide outcome: data and conclusions. Thus, it is somewhat difficult to assess this parameter.

8. The proposed purchase of equipment is: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.) Please comment:

Reviewer 10B-01 (Rating: 5)
No equipment, other than the usual wellbore materials necessary with a standard Bakken completion, are indicated for purchase in this proposal. Equipment for the tiltmeter service is the property of the vendor and is rented for the duration of the service period.

Reviewer 10B-02 (Rating: 2)
Approximately 83% of the total cost of the project is for installation, maintenance, and reclamation of the array. Not being familiar with the tiltmeter and array installation and maintenance, a detailed explanation of costs is needed.

Reviewer 10B-03 (Rating: 4)
No equipment will be purchased.

9. The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good. Please comment:

Reviewer 10B-01 (Rating: 3)
The vendor chosen for the tiltmeter services is well known in the industry for their competency in this technology. As with almost all technology services in the oil and gas industry, demand is high and availability is limited. Communication between the oil and gas operator and the service vendor is critical to insuring that resources and wellbore are both ready and available when needed. The equipment utilized for this service is not normally purchased by the oil and gas operator, but is rented for the duration of the service and remains the property of the vendor.

Reviewer 10B-02 (Rating: 2)
With my limited knowledge of this technology, I believe additional equipment would be needed for the project to be successful.

Marathon's Response
Surface tiltmeter mapping is an application that Pinnacle Technologies has extensive experience with, and they will be able to provide the equipment necessary for the project to be successful.

Reviewer 10B-03 (Rating: 4)
I can guess that subcontractor will provide reliable equipment and interpretation software.

10. The proposed budget "value"[1] relative to the outlined work and the financial commitment from other sources is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value. *(See below)* Please comment:

Reviewer 10B-01 (Rating: 5)
The value of the outcome of this project, should it be successful is very high relative to even the total cost of the necessary related work, which in itself is several times that of the tiltmeter services. Optimization of wellbore orientation to increase production and reserves has the potential to recover many times the cost of this tiltmeter project in just one well. The value of optimizing an entire development drilling plan early could result in production enhancements that could eclipse this proposal's cost to the state of North Dakota many times over. The operator has committed to spending far in excess of the requested matching 50% share of the cost of the tiltmeter service, and would spend that money regardless of whether this project is approved. Since the fracturing treatment will occur regardless, assisting with the cost of the tiltmeter service is an opportunity to acquire this data at a very discounted cost to the public.

Reviewer 10B-02 (Rating: 2)
I do not believe the objective can be accomplished as recommended.

Reviewer 10B-03 (Rating: 5)
Marathon provides significant amount of co-share.

[1] *"Value" – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.*

Financial commitment from other sources – A minimum of 50% of the total project must come from other sources to meet the program guidelines. Support less than 50% from Industrial Commission sources should be evaluated as favorable to the application.

Section C. Overall Comments and Recommendations:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund. General comments:

Reviewer 10B-01 (Funding May Be Considered)
Tiltmeter mapping surveys have a proven track record of helping determine hydraulic fracture orientation in many areas around the world. Like all technologies, regardless of how sophisticated or new, proper application is essential to the success of the operation and the quality of any data received. Other competing technologies exist that can provide similar data.

Of these, the investigators indicate they have not been able to acquire satisfactory results using wireline methods. It is unclear what these wireline methods entail, but common methods include resistivity or acoustic imaging logs and special acoustic tools that measure shear and compressional wave arrivals in different directions.

Additional methods for determining stress orientation, but not mentioned, are various oriented core analysis methods that measure strain relaxation to determine principle stress directions.

The most recent and probably the state of the art technology in fracture mapping is micro-seismic monitoring during fracturing. This technology has the advantage of also being able to determine the fracture height in addition to orientation. However, access to an available nearby wellbore is necessary for this technology and often the reason it is not utilized.

Reviewer 10B-02 (Do Not Fund)
As the understanding and knowledge of the Middle Bakken progresses this project could have merit. At the current time little is known about the extent of the natural fractures, the orientation, and the affect on production. Why are wells in Montana more productive than wells in North Dakota? I think we need to know more about the reservoir before we focus on the orientation of the created fracture.

Marathon's Response
The Middle Bakken play has a number of components. Fracture stimulation is the practice of choice in the play. This technology will help to address one of the elements that has a large impact on the economic viability of the Middle Bakken play. Other methods are necessary to progress the understanding of the plays other variables.

I am not familiar with this technology, but I think other technologies like Core Laboratories Pro Technics Division could be used with this technology to increase the value of the information.

At this time I recommend not to fund.

Marathon's Response

It is believed that this project could contribute significantly to the reservoir understanding referred to above. Marathon is actively using chemical flowback tracer and proppant tracer for Pro-Technics, but this technology addresses different aspects about the fracture stimulation than does the surface tiltmeter study.

Reviewer 10B-03 (Funding May Be Considered)

It is strongly recommended that the list of people responsible for the project completion included an experienced geomechanist. Solutions to the problems with production from Bakken are far from being obvious and understanding of natural fracture geometry may not be that useful. The problems can be partly explained by poor fracture connection within the natural +network. It is shown that fracture network is very regular, fractures are mostly sub-parallel and hydrofracturing provides little improvement as the fractures tend to grow parallel as well (e.g., Cramer 1991 a,b). Thus, I would suggest focusing efforts on choosing non standard hydrofracture techniques to create fractures providing the required conductivity. Pinnacle Technologies have understanding of fracture re-orientation and one may consider consulting with them regarding this aspect.

Reference:

Cramer D.D. 1991a. Understanding the reservoir important to successful stimulation. *Oil and Gas Journal*. April 22:53-61.

Cramer D.D. 1991b. Experience reveals better Bakken stimulation techniques. *Oil and Gas Journal*. April 29:56-61.